US 20120259538A1

(19) United States
(12) Patent Application Publication
OEXMANN
(10) Pub. No.: US 2012/0259538 A1
(43) Pub. Date: Oct. 11, 2012

(54) **VEHICLE PROXIMITY DETECTION AND CONTROL SYSTEMS**

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(21) Appl. No.: **13/484,646**

(22) Filed: **May 31, 2012**

Related U.S. Application Data

(60) Division of application No. 12/904,596, filed on Oct. 14, 2010, now Pat. No. 8,214,140, which is a division of application No. 12/043,545, filed on Mar. 6, 2008, now Pat. No. 7,835,864, which is a continuation-in-part of application No. 11/634,608, filed on Dec. 6, 2006, now abandoned, which is a continuation of application No. 11/092,038, filed on Mar. 29, 2005, now abandoned, which is a continuation of application No. 10/462,985, filed on Jun. 17, 2003, now Pat. No. 6,924,736, which is a continuation of application No. 09/788,778, filed on Feb. 20, 2001, now abandoned.

(60) Provisional application No. 60/183,726, filed on Feb. 20, 2000.

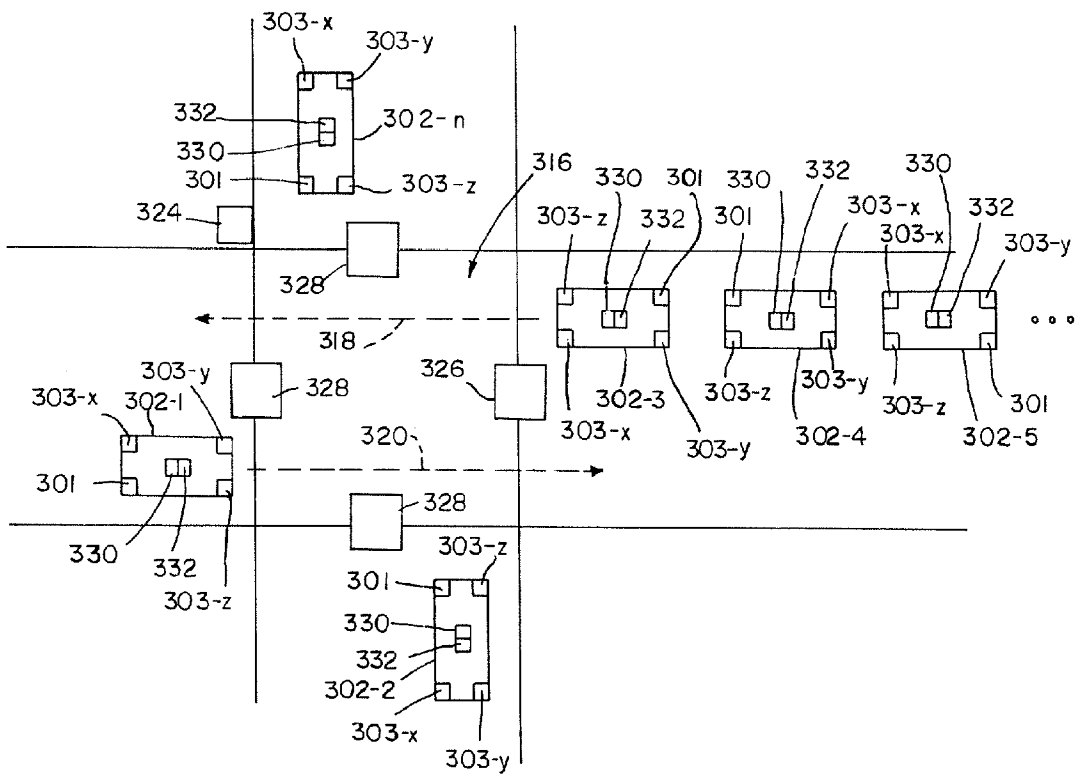
Publication Classification

(51) **Int. Cl.**
G08G 1/16 (2006.01)

(52) **U.S. Cl.** **701/301**

(57) **ABSTRACT**

A system for reducing the likelihood of collision between a first vehicle and a second vehicle. Each vehicle includes a device for receiving global positioning system (GPS) signals, generating at least one of a time, position and velocity signal based on the received GPS signals, generating at least one of a time, position and velocity signal based upon the motion of the vehicle, comparing the received and generated signals, generating a corrected vehicle signal, and transmitting the corrected vehicle signal. A transportation network generates transportation network data including at least one of: network capacity data, network layout data, and network traffic data. The second vehicle's device stores the transportation network data, receives the corrected first vehicle signal, and calculates from the transportation network data and corrected first and second vehicle signals the likelihood that the positions of the first and second vehicles will coincide at some time on the transportation network.



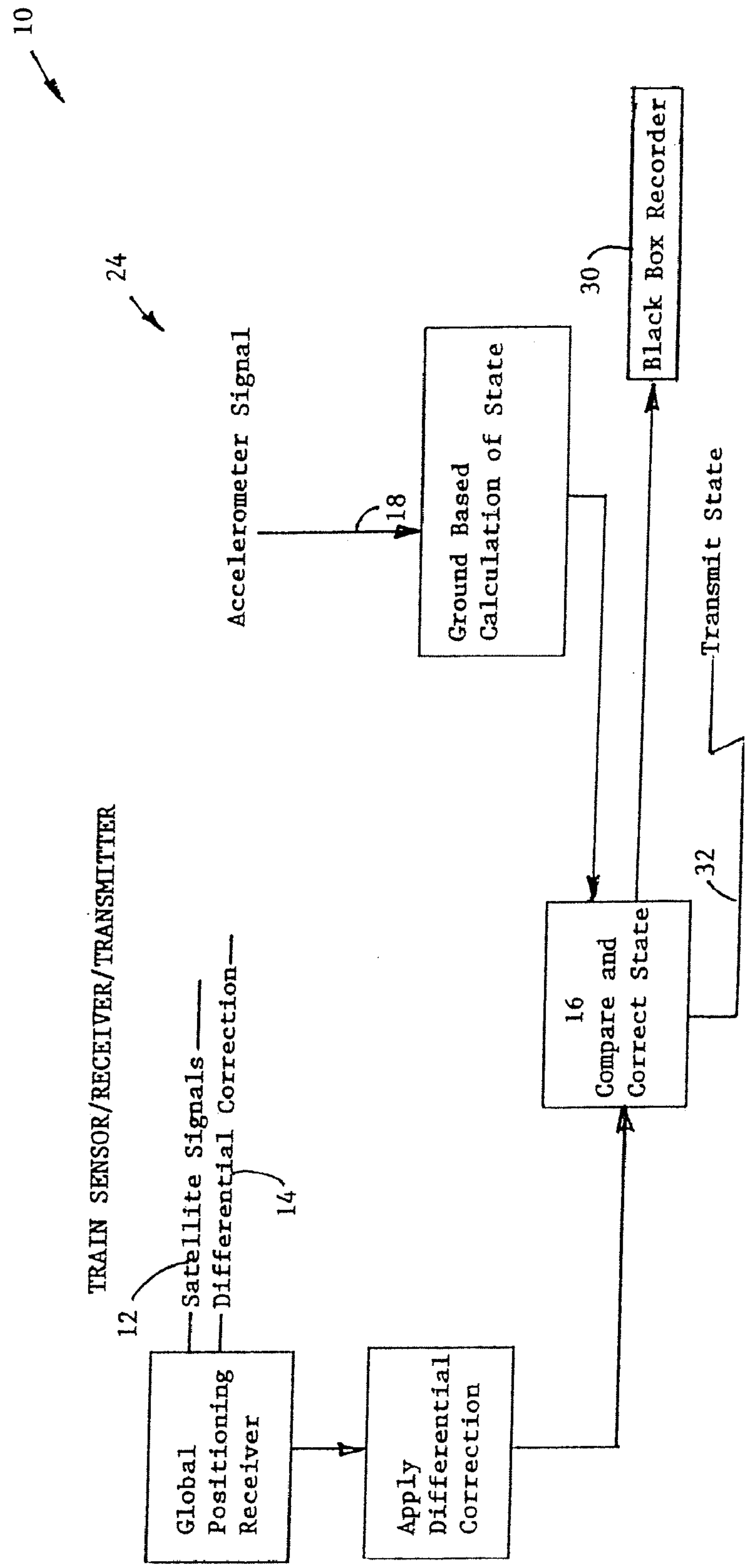

10
24
TRAIN SENSOR/RECEIVER/TRANSMITTER
12
Satellite Signals
Differential Correction
14
Global Positioning Receiver
Apply Differential Correction
16
Compare and Correct State
32
Transmit State
Accelerometer Signal
18
Ground Based Calculation of State
30
Black Box Recorder

FIG. 1

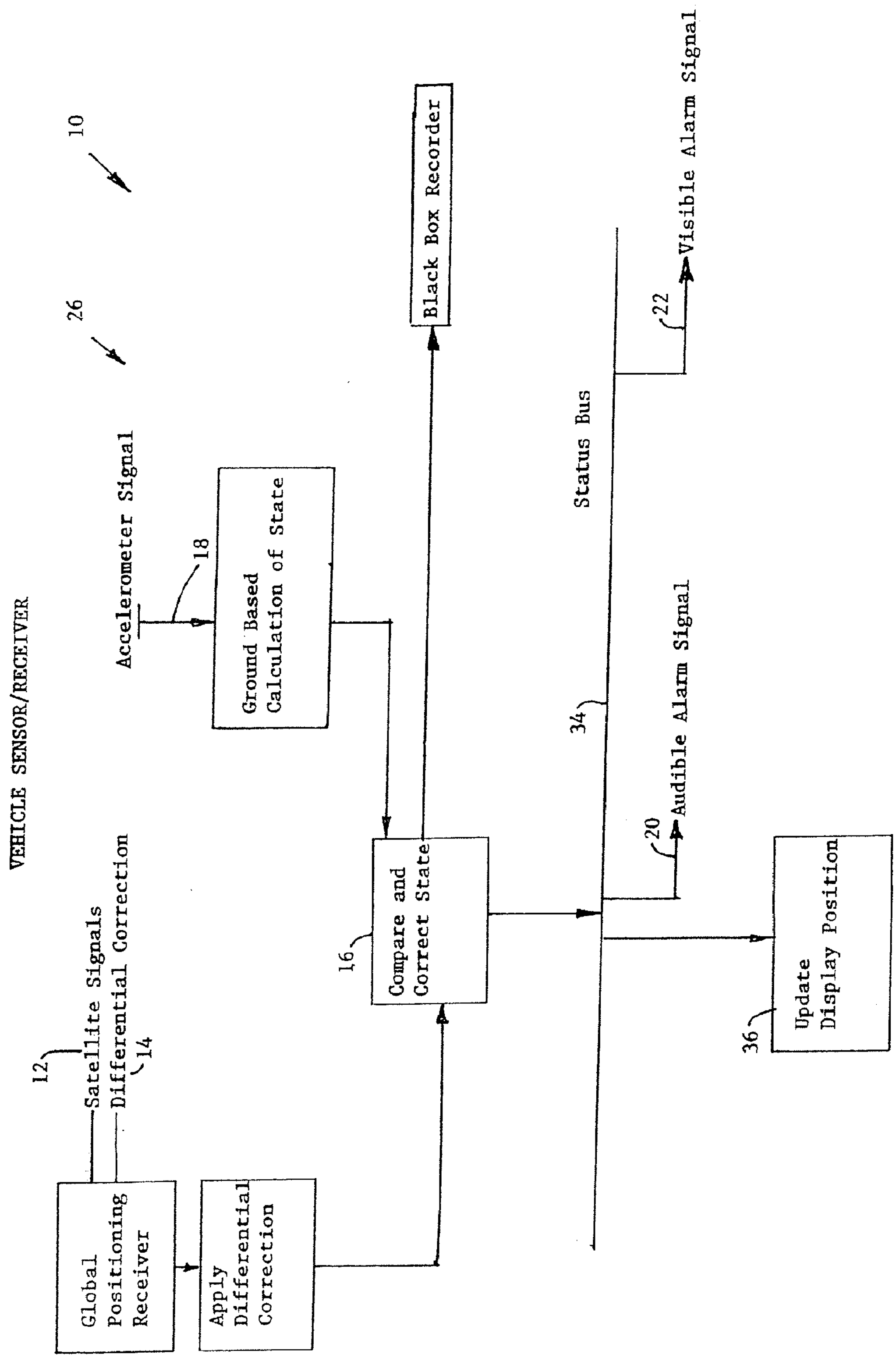

10
26
VEHICLE SENSOR/RECEIVER
12
Satellite Signals
Differential Correction
14
Global Positioning Receiver
Apply Differential Correction
Accelerometer Signal
18
Ground Based Calculation of State
16
Compare and Correct State
Black Box Recorder
Status Bus
34
22
Visible Alarm Signal
20
Audible Alarm Signal
36
Update Display Position

FIG. 2

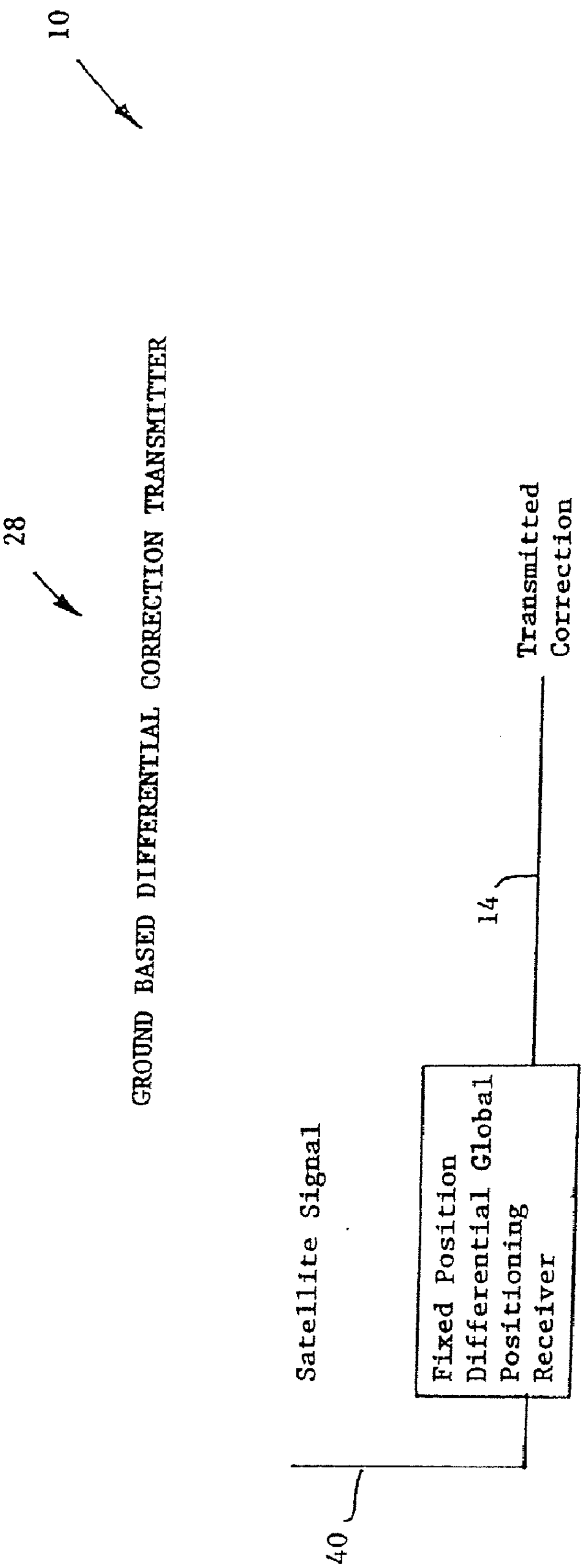

10
28
GROUND BASED DIFFERENTIAL CORRECTION TRANSMITTER
Transmitted Correction
14
Satellite Signal
Fixed Position Differential Global Positioning Receiver
40

FIG. 3

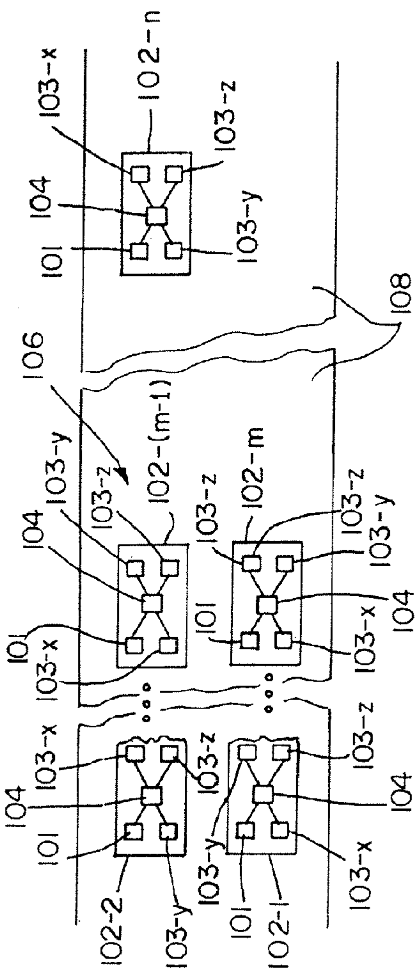

101
102-1
102-2
102-m
102-(m-1)
102-n
103-x
103-y
103-z
104
106
108

FIG. 4

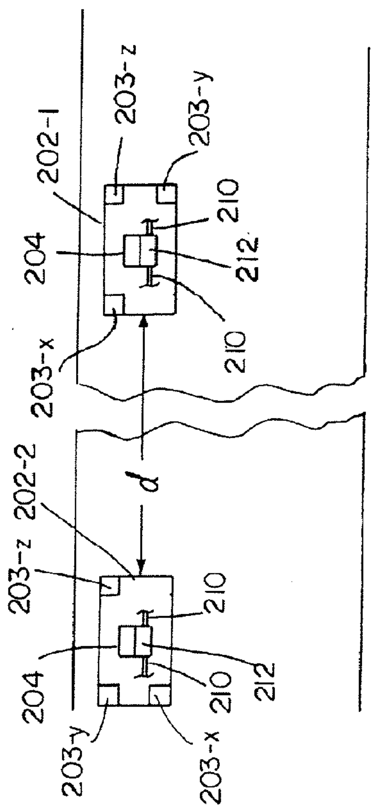

202-1
202-2
203-x
203-y
203-z
204
210
212
d

FIG. 5

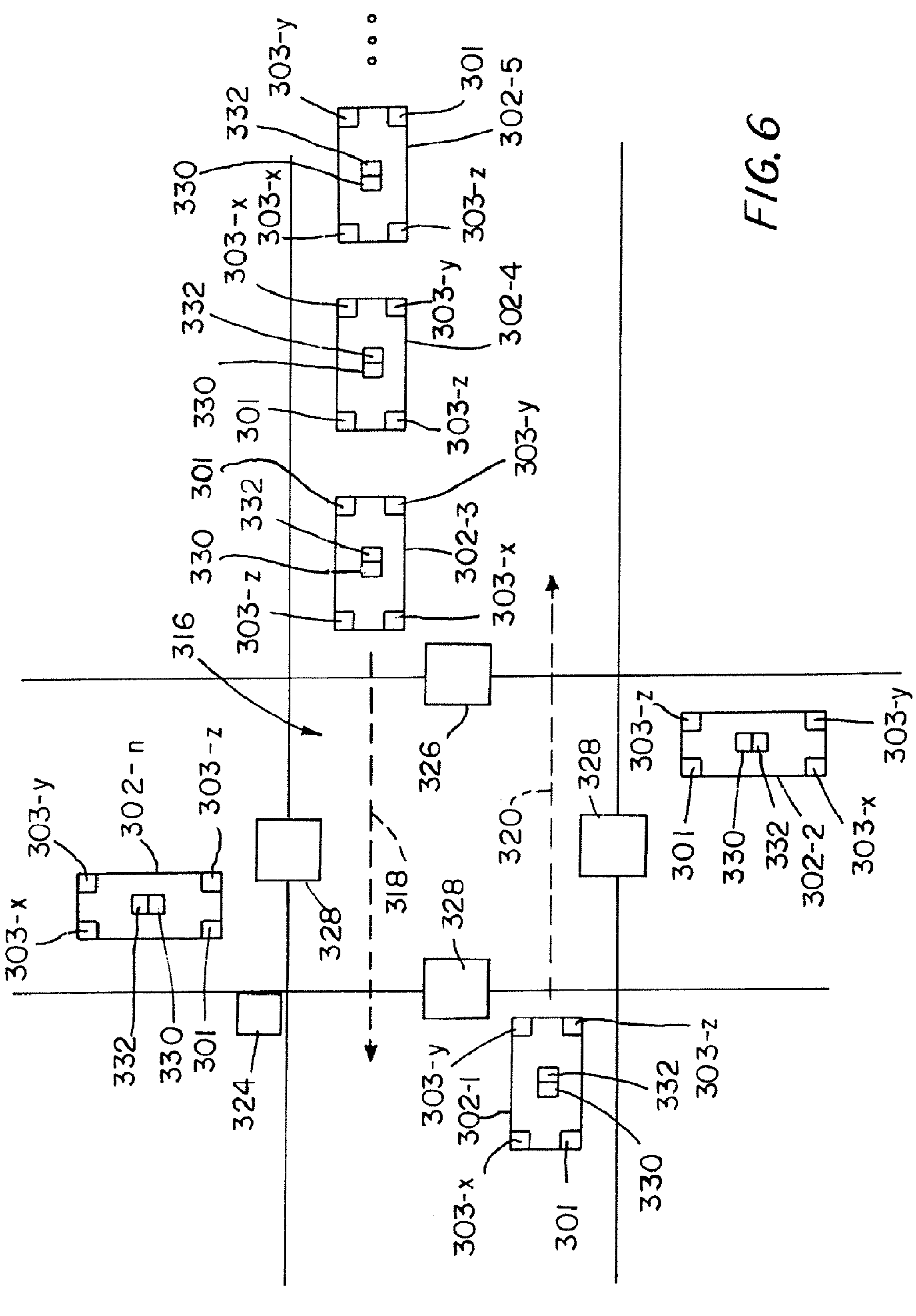

303-y
332
330
303-x
303-x
301
302-5
303-z
303-y
332
330
303-y
302-4
301
303-z
301
332
330
303-z
303-y
302-3
303-x
316
326
328
318
320
328
328
324
303-x
303-y
302-n
303-z
332
330
301
303-z
303-y
301
330
332
302-2
303-x
303-y
302-1
303-x
301
330
332
303-z

FIG. 6

VEHICLE PROXIMITY DETECTION AND CONTROL SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. Ser. No. 11/634,608, now abandoned. U.S. Ser. No. 11/634,608 is a continuation of U.S. Ser. No. 11/092,038, now abandoned. U.S. Ser. No. 11/092,038 is a continuation of U.S. Ser. No. 10/462,985, now U.S. Pat. No. 6,924,736. U.S. Ser. No. 10/462,985 is a continuation of U.S. Ser. No. 09/788,778, now abandoned. U.S. Ser. No. 09/788,778 claims the benefit of U.S. Ser. No. 60/183,726 filed on Feb. 20, 2000. The disclosures of all of U.S. Ser. No. 11/634,608, U.S. Ser. No. 11/092,038, U.S. Ser. No. 10/462,985, U.S. Ser. No. 09/788,778 and U.S. Ser. No. 60/183,726 are hereby incorporated herein in their entireties by reference.

FIELD OF THE INVENTION

[0002] This invention relates to vehicle proximity detection and control systems. It is disclosed in the context of systems for detecting potential concurrent location of multiple vehicles, systems for adaptive control of vehicle speeds and systems for control of traffic flow through an intersection. However, it is believed to be useful in other applications as well.

DISCLOSURE OF THE INVENTION

[0003] According to an aspect of the invention, multiple vehicles are each equipped with a global positioning system (GPS) and a plurality of accelerometers to provide information related to said vehicle's current state. A controller is provided to predict concurrent presence of at least two of said vehicles at a location at some future time. At least one of said vehicles further includes an indicator, for example, an audible and/or visual indicator, to indicate the potential for concurrent presence at said location in adequate time for the operator of said at least one of said vehicles to take appropriate evasive action to avoid concurrent presence at said location.

[0004] Illustratively according to this aspect of the invention, each of the multiple vehicles is equipped with three accelerometers.

[0005] According to another aspect of the invention, multiple vehicles are each equipped with a global positioning system (GPS) and a plurality of accelerometers to provide information related to said vehicle's current state, a controller to identify vehicle speed, and an interface between the controller and said vehicle's throttle to control acceleration and deceleration.

[0006] Illustratively according to this aspect of the invention, the controller comprises a controller for maintaining a substantially constant distance behind a vehicle immediately ahead of said vehicle.

[0007] Illustratively according to this aspect of the invention, the controller comprises a controller for maintaining a substantially constant distance behind a vehicle immediately ahead of said vehicle depending at least in part on the speed of said vehicle.

[0008] Illustratively according to this aspect of the invention, the controller comprises a controller for preventing said vehicle from exceeding a preset value.

[0009] According to another aspect of the invention, multiple vehicles are each equipped with a global positioning system (GPS) to provide information related to said vehicle's current state and a transceiver. A controller is provided for controlling traffic flow through an intersection during periods when traffic flow through said intersection is below a predetermined threshold. The controller includes a transmitter for communicating with the transceiver in each said vehicle.

[0010] Illustratively according to this aspect of the invention, said controller comprises a controller for controlling traffic flow using historical time of day (TOD) traffic flow rates.

[0011] Illustratively according to this aspect of the invention, said controller comprises a controller for controlling traffic flow using current arrivals at the intersection.

[0012] Illustratively according to this aspect of the invention, said controller further comprises a controller for giving preference to a first direction of traffic flow at a first time of day and to a second and different direction of traffic flow at a second time of day.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The invention may best be understood by referring to the following detailed description and accompanying drawings which illustrate the invention. In the drawings:

[0014] FIG. **1** illustrates a partly block and partly flow diagram for a component constructed according to the invention;

[0015] FIG. **2** illustrates a partly block and partly flow diagram for a component constructed according to the invention;

[0016] FIG. **3** illustrates a partly block and partly flow diagram for a component constructed according to the invention;

[0017] FIG. **4** illustrates a partly block and partly flow diagram for a component constructed according to the invention;

[0018] FIG. **5** illustrates a partly block and partly flow diagram for a component constructed according to the invention; and,

[0019] FIG. **6** illustrates a partly block and partly flow diagram for a component constructed according to the invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0020] Referring now to FIG. **1**, a system **10** provides a warning to vehicles traveling toward a railroad crossing of impending danger from a train either blocking the crossing or close enough to the crossing that there is a danger of collision. The positions, speeds and directions of travel of both the vehicle and train are determined using Global Positioning System (GPS) signals **12** and corrections from Differential Global Positioning Satellite (DGPS) signals **14** are used to calculate the distance between the two vehicles as well as project their arrival at the crossing. This information is further compared and corrected **16** by calculated position and velocity, using data **18** from accelerometer sensors on the vehicle and train.

[0021] The vehicle/train state can be one of the following: no known train within receiving distance of a receiver in the vehicle; a train has been detected within range of the receiver; the train and vehicle are both approaching the crossing at such a rate that, from their current positions, if they continue there is danger of collision; the train and vehicle are both approaching the crossing at such a rate that, from their current positions, if they continue a collision is practically certain; and, interference is such that no reliable signal can be received from the satellite or train on a timely basis.

[0022] Audible **20** or visual **22** indication, or both, of the above states can be provided.

[0023] The system **10** is not intended to replace the existing light and crossing gates in place at some crossings.

[0024] There are three major communicating components to the system **10**. Referring to FIG. **1**, the first is a Train Sensor/Receiver/Transmitter (TSRT) **24**. One of these will be placed on a car or engine at each end of the train. Referring to FIG. **2**, the second component is a Vehicle Sensor/Receiver (VSR) **26**. One of these will be placed on each road vehicle. Referring to FIG. **3**, the optional third component is a Ground-Based Differential Correction Receiver/Transmitter (GBDCR) **28**. These will be positioned so that at any time each train and vehicle will be close enough to at least one, so that the train and vehicle can receive the correction signal.

[0025] Referring back to FIG. **1**, the the TSRT **24** receives GPS satellite signals **12**, receives differential GPS correction **14** when the GPS signal is scrambled, and calculates **16** at least one of, and illustratively all of, time, position and velocity based on this input. The TSRT **24** maintains a separate time and/or position and/or velocity based on a processor time and an onboard signal **18** from an accelerometer, compares and computes **16** a corrected time and/or position and/or velocity based on both. The TSRT **24** further records **30** the current state, time and/or position and/or velocity to a black box for a permanent log on the train and vehicle. The TSRT **24** also broadcasts **32** a transmission, for example, a digital transmission, of this state to be received and processed by any vehicle equipped with a VSR **26**.

[0026] Referring back to FIG. **2**, the VSR **26** receives GPS satellite signals **12**, receives differential GPS correction **14** when the GPS signal is scrambled, and calculates **16** time and/or position and/or velocity based on this input. The VSR **26** maintains a separate time and/or position and/or velocity based on a processor time and an onboard signal from an accelerometer **18**. The VSR **26** compares and computes **16** a corrected time and/or position and/or velocity based on both the GPS-calculated time and the onboard accelerometer **18**-based time. The VSR **26** records **30** the current state, time and/or position and/or velocity to a black box for a permanent log. The VSR **26** determines the current status, vehicle time and/or position and/or velocity, and the train time and/or position and/or velocity. The VSR **26** maintains this vehicle/train state on its system bus **34** in order to provide to warning devices the information needed to provide the appropriate warning. The VSR **26** maintains the current train state and vehicle state on the system bus **34** to be used by a display **36** processor. The display **36** processor presents a map with the surrounding roadway, train track and intersection, marking the current position(s) of train(s) and/or vehicle(s). It should be understood that many road vehicles are already equipped with GPS receivers. In such cases, all that would need to be provided is an output from the existing GPS receiver to the VSR **26**.

[0027] Referring again to FIG. **3**, if the GPS signal is scrambled, the GBDCR **28** receives differential correction signals **40** from the satellite, and relays corrections **14** to all trains and vehicles equipped with a TSRT **24** or VSR **26** by broadcast.

[0028] It is contemplated that part of the vehicle state that is transmitted will be the vehicle's identity, for example, the VIN number or some other unique identification.

[0029] Although the invention has been presented in the context of a system for avoiding collisions between trains and road vehicles, it is clear that the same components can be used on any two or more trains or other vehicles to avoid collisions between them. Each participating vehicle needs both components, the TSRT **24** and the VSR **26**. Since the two components **24**, **26** share some functionality, integrating them into a single component is a reasonable approach to satisfying their requirements.

[0030] Examples of such uses in vehicle-to-vehicle collision avoidance systems include, but are not limited to: use on emergency vehicles, such as ambulances and fire trucks, and other vehicles to warn the other vehicles of the proximity of emergency vehicles; use on two vehicle traveling the same route in the same direction in low visibility conditions, such as fog, rain or snow, to warn of proximity; and for identification of congestion caused by road construction, accidents or the like.

[0031] Referring now to FIG. **4**, the described system **100** does not rely on line of sight, but rather on two independent devices, a GPS **101** and accelerometers **103** (in the illustrated embodiments, three accelerometers **103**-x, **103**-y, **103**-z) to determine a vehicle **102-1**, **102-2**, . . .'s current state, within acceptable limits. In an embodiment, all vehicles **102-1**, **102-2**, . . . are equipped with such systems. Functionality is added to the controller **104** of each system **100** to recognize, for example, obstruction **106** of all lanes of a highway **108**, well before the obstruction **106** can be seen. This permits a driver of a vehicle **102**-n approaching such an obstruction **106** to avoid a collision with one or more of the backed-up vehicles **102-1**, **102-2**, . . . obstructing all lanes. The driver of vehicle **102**-n will be warned in adequate time to take appropriate action.

[0032] Referring now to FIG. **5**, in another embodiment, each vehicle is equipped with GPS **201** and accelerometers **203**-x, **203**-y, **203**-z. Additional functionality is provided for the controller **204**, and the linkage **210** controlling vehicle **202-1** speed is interfaced **212** with the controller **204**, so that the controller **204** can effectively control vehicle **202-1** acceleration and deceleration. The resulting control provides an adaptive cruise control (hereinafter sometimes ACC). The present embodiment keeps to a minimum the additional hardware required to implement ACC. Adding code to the controller **204** (which in the case of most land vehicles includes a real-time or quasi-real time microprocessor) and an output to the interface **212** to control the vehicle **202-1**'s speed and maintain a constant distance d behind a vehicle **202-2** immediately ahead, depending on speed, while preventing acceleration beyond the speed limit or a preset value, is a much more economical implementation of ACC.

[0033] Referring now to FIG. **6**, in another embodiment, each vehicle **302-1**, **302-2**, . . . is equipped with GPS **301** and accelerometers **303**-x, **303**-y, **303**-z. Smooth flow of vehicles **302-1**, **302-2**, . . . is maintained through an intersection **316** without stopping while the throughput is slow enough. This results in less total time idling at the intersection **316** for an optimum number of vehicles **302-1**, **302-2**, ... This results in less fuel usage and shortens commuting times. Using historical time of day (hereinafter sometimes TOD) traffic flow rates and currently observed arrivals at the intersection **316**, the system adapts. The flow algorithm may be biased, for example, to give precedence in the direction of primary traffic flow, for example, inbound **318** to a city center during the morning hours, and outbound **320** toward suburban areas during the evening hours. When traffic reaches a threshold level, such as during rush hours, control is returned to standard traffic light **322** timing and vehicle **302-1**, **302-2**, . . . operators. The hardware may be as simple as a controller **324** at the intersection **316** plus a flashing yellow traffic light **326** in the direction of precedence and flashing red traffic lights **328** in other directions, or it may be more complex. Vehicles **302-1**, **302-2**, . . . have installed GPS enabled receivers **330** and transceivers **332** to communicate with the controller **324** at the intersection.

1-11. (canceled)

12. A system for reducing the likelihood of collision between a first vehicle and a second vehicle, the first vehicle including a first device for receiving global positioning system (GPS) signals, generating at least one of a first time, position and velocity signal based on the received GPS signals, generating at least one of a second time, position and velocity signal based upon the motion of the first vehicle, comparing the first and second signals, generating a corrected first vehicle signal, and transmitting the corrected first vehicle signal, the second vehicle including a second device for receiving GPS signals, generating at least one of a third time, position and velocity based on the received GPS signals, generating at least one of a fourth time, position and velocity based on the motion of the second vehicle, comparing the third and fourth signals, generating a corrected second vehicle signal, a transportation network for generating transportation network data including at least one of: network capacity data, network layout data, and network traffic data, the second device further storing the transportation network data, receiving the corrected first signal, and calculating from the transportation network data and corrected first and second vehicle signals the likelihood that the positions of the first and second vehicles will coincide at some time on the transportation network.

13. The system of claim **12** further including a third device for receiving differential GPS (DGPS) correction signals and retransmitting the DGPS correction signals, the first device receiving the DGPS correction signals and combining the DGPS correction signals with the GPS signals to generate the at least one of the first time, position and velocity signal.

14. The system of claim **13** wherein the second device receives the DGPS correction signals and combines the DGPS correction signals with the GPS signals to generate the at least one of the third time, position and velocity signal.

15. The system of claim **12** further including a third device for receiving differential GPS (DGPS) correction signals and retransmitting the DGPS correction signals, the second device receiving the DGPS correction signals and combining the DGPS correction signals with the GPS signals to generate the at least one of the third time, position and velocity signal.

16. The system of claim **12** wherein at least one of the first vehicle and the second vehicle further includes a third device for recording at least one of the corrected first vehicle signal and the corrected second vehicle signal.

17. The system of claim **12** wherein the second device further produces an indication to an occupant in the second vehicle that it is likely that the positions of the first and second vehicles will coincide at some time on the transportation network.

18. The system of claim **12** wherein the second vehicle includes a display coupled to the second device for indicating at least one of: the location of the first vehicle; the velocity of the first vehicle; the direction of travel of the first vehicle; the location of the second vehicle; the velocity of the second vehicle; the direction of travel of the second vehicle; and, the layout of the transportation network.

* * * * *